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**New Material Transition From an  
OEM Perspective**

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Materials – Composites (AIM-C) which is jointly  
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# Agenda



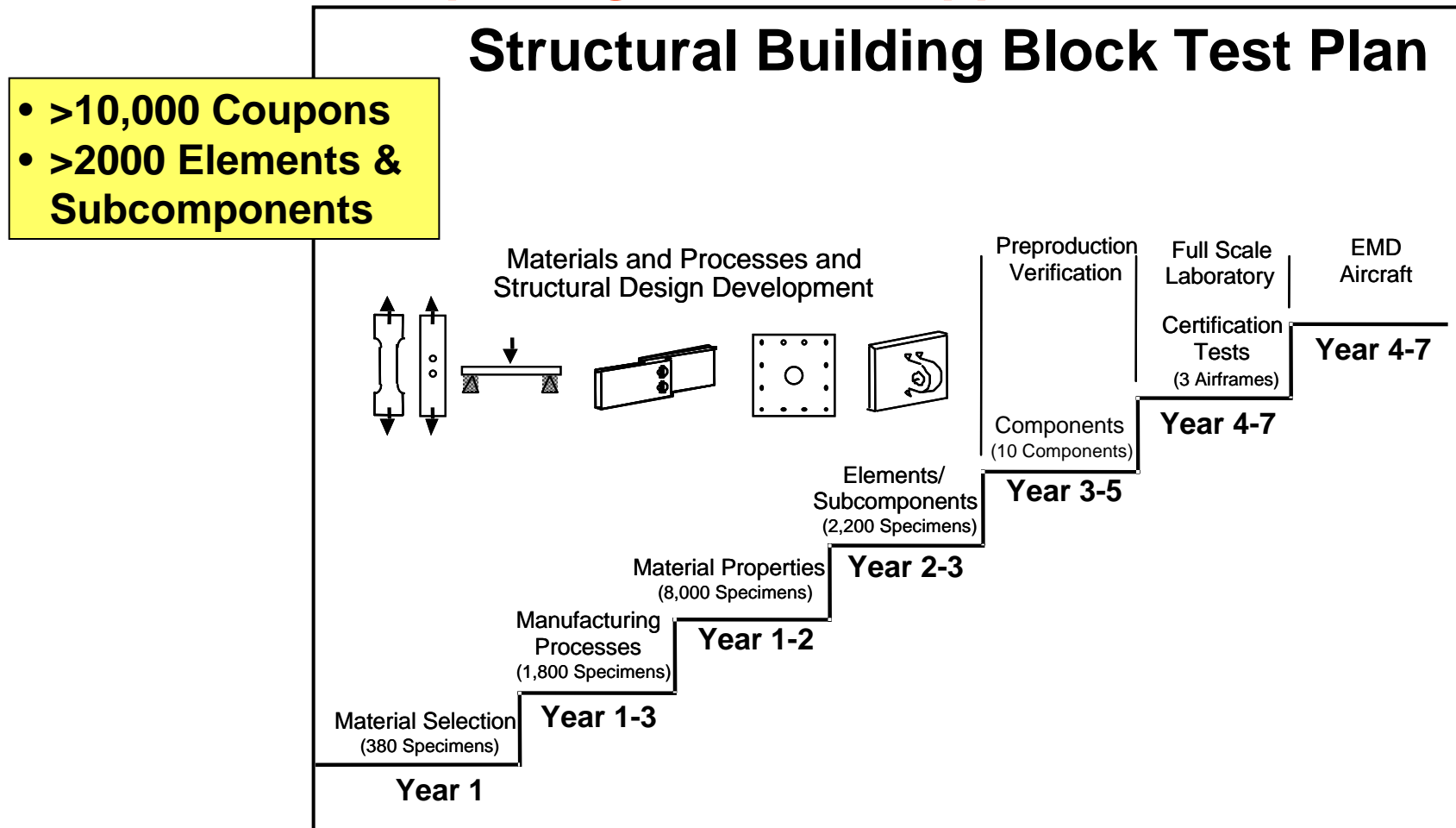
*In the composites industry, there is significant, widespread confusion and frustration relating to material transition onto products. This presentation goes into several areas pertaining to an increased understanding from a multiple discipline perspective.*

- **Background**
- **Maturity**
- **Disciplines**
- **Conformance**
- **Summary**

# Background



*Transition means putting it onto an application...*



*...Application Acceptance is Through Certification  
With Stepwise Risk Reduction*

# Background



## *Designer Data/Information Needs for Application Certification*

### Structural

- Strength and Stiffness
- Weight
- Service Environment
  - Temperature
  - Moisture
  - Acoustic
  - Chemical
- Fatigue and Corrosion Resistant
- Loads & Allowables

### Manufacturing

- Recurring Cost, Cycle Time, and Quality
- Use Common Mfg. Equipment and Tooling
- Process Control
- Inspectable
- Machinable
- Automatable
- Impact on Assembly

### Supportability

- O&S Cost and Readiness
- Damage Tolerance
- Inspectable on Aircraft
- Repairable
- Maintainable
  - Accessibility
  - Depaint/Repaint
  - Reseal
  - Corrosion Removal
- Logistical Impact

### Material & Processes

- Development Cost
- Feasible Processing Temperature and Pressure
- Process Limitations
- Safety/Environmental Impact
- Useful Product Forms
- Raw Material Cost
- Availability
- Consistency

### Miscellaneous

- Observables
- EMI/Lightning Strike
- Supplier Base
- Applications History
- Certification Agency & Status
  - USN
  - USAF
  - ARMY
  - FAA

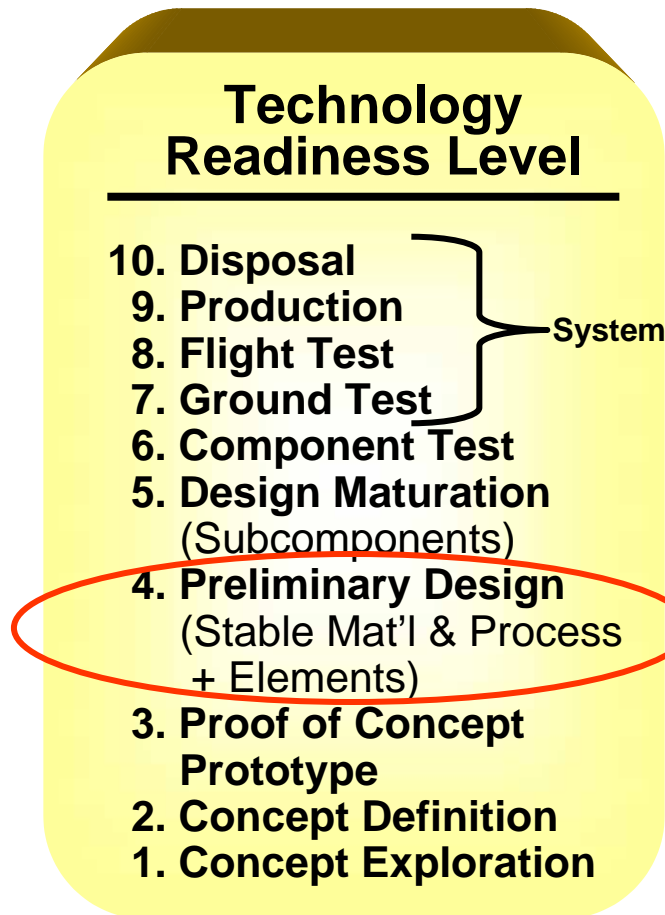
**Risk in Each Area is Dependent Upon Application's Criticality and Material's Likelihood of Failure**

# Maturity



## Technology Readiness Level (TRL) For Maturity

### Designer Perspective



### PROS

- Looks at maturity from a designer/system viewpoint
- Broken down into specific activity areas
- Is geared towards application products and systems for readiness

### CONS

- Does not take into account different discipline perspectives
- Does not address detailed areas/items at each readiness level

**Based on NASA, Air Force and ONR Technology Maturity Level Approaches**

# Maturity



## *Readiness Levels From a Technologist Viewpoint*

### *Technologist Perspectives*

#### **Readiness Level**

9. Industry Std
8. Production
7. Qualified Mat'l/Process/Mfg
6. Pre-Production
5. Pilot Production
4. Lab/Prototype Production
3. Beaker/Bench Product
2. Theoretical/Beaker Product
1. Concept Exploration

#### **PROS**

- Looks at maturity from a technologist viewpoint
- Broken down into specific activity areas
- Is geared towards materials, processing and manufacturing for readiness

#### **CONS**

- Is not tied/connected to TRL's from the system or application viewpoint
- Does not take into account different discipline perspectives
- Does not address detailed areas/items at each readiness level

# Maturity



- **Certification**
  - Application Requirements/Needs Demonstrated
  - Stepwise Risk Reduction (Building Block Approach)
  - Performance Characteristics for Primary/Secondary/Air Loaded Structures
- **Qualification**
  - Materials and Processing are Stable
  - Material and Processing Specifications
- **Transition**
  - Customer Acceptance for an Application or Applications



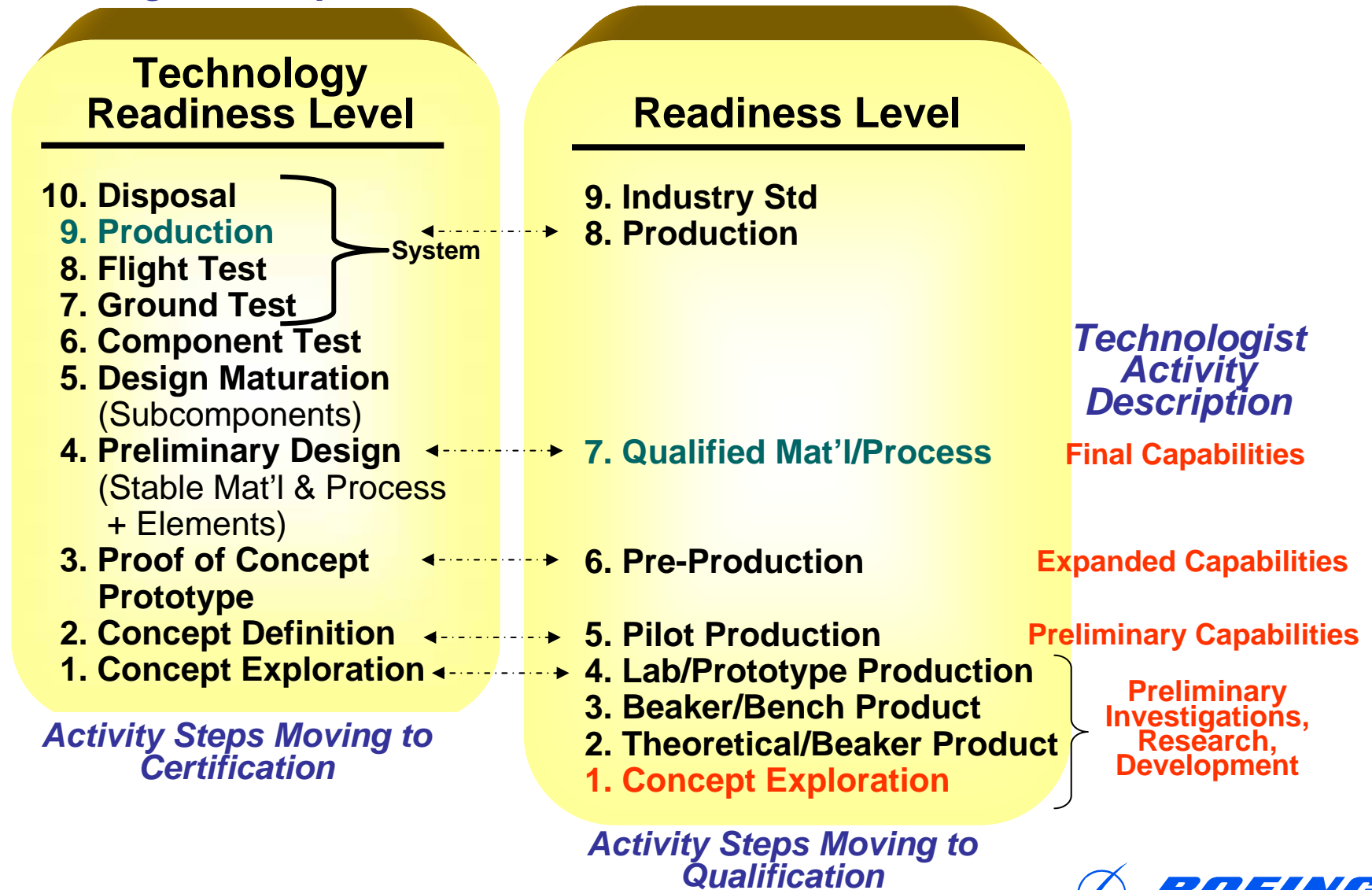
# Maturity



## Connections/Correlations for Readiness Levels

### Designer Perspective

### Technologist Perspectives



# Multiple Disciplines



TRL	0	1	2	3	4	5	6	7	8	9	10
<b>Certification</b>	Qualification Plan Assessment	Certification Elements Documented	Certification Plan Documented	Certification Plan Approved	Elements	Subcomponent Testing	Full Scale Component Testing	Full Scale Airframe Tests	Flight Test	Production Approval	Disposal Plan Approval
<b>Application/ Design</b>	Technology Readiness Review	System Requirements Review	Project Planning Review	Preliminary Design Review	Critical Design Review	Full Scale Test Readiness Review	Ground Test Certification Review	Flight Test Certification Review	Production Readiness Review	Production Support	Recycle or Dispose
<b>Assembly/ Quality</b>	Preliminary Assembly Concept Assessed	Assembly Concept	Assembly Plan Definition	Key Assembly Detail Definitions	Key Assembly Details Tested	Subcomponents Assembled	Components Assembled	Airframe Assembled	Flight Vehicles Assembled	Production	Disassembly for Disposal
<b>Survivability</b>	General Requirements Assessed	Requirements Definition	Concept Definition	Proof of Concept	Preliminary Design Data and Guidelines	Design Allowables and Guidelines Defined	Critical Details Testing	Ground Test	Flight Test	Production Support	Operations Support & Disposal
<b>Fabrication/ Quality</b>	Fabrication Capability Demonstrated	Unfeatured-Panel Fabrication	Feature Based Generic Small/Subscale Parts Fabricated	Property-Fab Relationships Tested/ Target Application Pilot Production of Generic Full Size Parts	Process Specs/ Effects of Fab Variations Tested/ Elements Fab'd/ Production Representative Parts Fab'd	Subcomponents Fab'd	Full Scale Components Fabricated	EMD Fabrication	Low Rate Initial Production (LRIP)	Production	Recycle or Disposal
<b>Supportability</b>	Repair Requirements Assessed	Repair Items/Areas Identified	Repair Materials & Processes Identified	Repair Materials & Processes Documented	Fab Repairs Identified	Fab Repair Trials/ Subcomponent Repairs	Component Repairs	Production Repairs Identified	Flight Qualified Repairs Documented	Repair-Replace Decisions	Support for Recycle or Disposal Decisions
<b>Structures &amp; Durability</b>	Preliminary Properties-Characteristics Assessed	Preliminary Properties-Characteristics	Initial Properties	Design To Properties Developed	Preliminary Design Allowables	Final Design Allowables	Allowables for Critical Design Features	Production and Test Support	Certified Allowables	Flight Tracking/ Production Support/ Fleet Support	Retirement for Cause
<b>Materials</b>	Lab-Prototype Materials	Lab-Prototype Materials Reproducible	Pilot Production Materials	Pre-Production Materials	Production Scaleability Validated	EMD Material Supplied	EMD Material Supplied	EMD Material Supplied	LRIP Material Supplied	Production Material Supplied	Support for Recycle or Disposal Decisions
<b>Cost/Schedule/ Benefits</b>	Cost Benefit Elements ID'd & Assessed	Cost Benefit Elements ID'd & Projected	ROM Cost Benefit Analysis	Cost Benefit Analysis Reflect Size Lessons Learned	Cost Benefit Analysis Reflect Element and Production Representative Part Lessons Learned	Cost Benefit Analysis Reflect Subcomponent Fab & Assembly Lessons Learned	Cost Benefit Analysis Reflect Component Fab & Assembly Lessons Learned	Cost Benefit Analysis Reflect EMD Lessons Learned	Cost Benefit Analysis Reflect LRIP Lessons Learned	Cost Benefit Analysis Reflect Production Lessons Learned	Cost Benefit Analysis Reflect Disposal Lessons Learned
<b>Intellectual Rights</b>	Concept Protection Plan Developed	Protection Plan Documentation	Patent Disclosure Filed	Proprietary Rights Agreements	Data Sharing Rights	Vendor Agreements	Material and Fabrication Contracts	Production Rate Contracts	Vendor Requal Agreements	Post-Production Agreements	Liability Termination Agreements

**...Multiple Disciplines Have Different Perspectives for Technical Maturity Level Exit Criteria**

# Multiple Disciplines

## Structures and Durability Breakout



Exit Criteria Vary  
According to  
Application

In-plane Ultimate Strength -- Unnotched Compression	Bond/Interlaminar Joint Strength - Final Failure
In-plane Ultimate Strength -- Unnotched Tension	
Ultimate Strength -- Combined Loads	Bolted Joint - Bearing/Bypass
In-plane Ultimate Strength -- Open Hole Compression	
In-plane Ultimate Strength -- Open Hole Tension	Maximum Deflection
Ultimate Strength -- Open Hole, Combined Loads	Residual Strength -- BVID, Compression
Stability - Global/Panel	Residual Strength -- Penetrations, Tension
	Residual Strength -- Penetrations, Compression
Stability - Skin Buckling	Residual Strength -- Penetrations, Combined Loads
Stability - Stringer Crippling	Local Stability - Face wrinkling (Sandwich Only)
Stability - Stringer Column Buckling	Local Stability - Intracell Buckling (Sandwich Only)
Bond/Interlaminar Joint Strength - Damage Initiation	Local Stability - Shear Crimping (Sandwich Only)

Exit Criteria Tends to  
Vary According to  
OEM and Customer

Durability/Life - Microcracking	Material Mechanical Properties - Primary (Tension, Compression, Shear, Bearing By-pass)
Durability/Life - Delamination Growth	Material Mechanical Properties - Secondary (CTE, Poisson's, Fracture Toughness, )
Durability/Life - Stiffness Degradation	Material Mechanical Properties - Other ( )
Durability/Life - Bearing Strength Degradation	Material Durability/Life Properties - Environmental Impact on Properties
	Material Durability/Life Properties - Impact Resistance and Fatigue
	Material Durability/Life Properties - Solvent Resistance

# Multiple Disciplines

## *Materials, Processing and Producibility Breakout With Example Exit Criteria*



MATERIAL	Critical functions/ characteristics of material/ ingredients demonstrated. New material within state-of-the-art. Indirect material requirements identified. Facility requirements identified.
PROCESSES	Critical functions/ characteristics of processing demonstrated. New process operates within state-of-the-art. Facility requirements identified. Indirect materials or process steps identified.
EQUIPMENT	Critical functions/ characteristics of individual equipment pieces demonstrated. Indirect materials and facility requirements identified. Equipment accuracy requirements defined.
TOOLING	Critical functions/ characteristics of individual tooling pieces demonstrated. Indirect materials and facility requirements identified. Tooling accuracy requirements defined.
VARIABILITY	Variabilities roughly characterized.

QUALITY - IN-PROCESS	Critical quality functions/characteristics demonstrated. Indirect material and/or process steps identified. Facility requirements identified. Defects identified.
QUALITY - FINAL PRODUCT	Critical quality functions/characteristics demonstrated. Indirect material and/or process steps identified. Facility requirements identified. Defects identified.
APPLICATION MATURITY	Critical functions/characteristics demonstrated; physical phenomena understood.
COST/BENEFIT ANALYSIS	Key costs/benefits have had a preliminary assessment for quantification.
SUPPORTABILITY	Critical repair functions and characteristics demonstrated.
REGULATORY	Regulatory issues understood.
Intellectual Property	Reduction to practice in progress. Strategy to issue patents or preserve technology as trade secret accepted.

- **Combines Both Objective and Subjective Areas**
  - Includes Property and Characteristic Measurements
  - Includes Production Readiness Assessments
- **Each Individual Material and Processing/ Producibility Step Needs to be Addressed**

# Conformance



.....Varies According to Application, Maturity, Discipline and Customer To Meet Requirements

Tension	Laminate	Layup 1 (Quasi)	Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Resin	Prepreg	Fiber	Processing/Producibility
				Open Hole				
				Filled Hole				
		Layup 2 (Hard)	Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2				
Compression	Lamina		Longitudinal	Open Hole Tensile Strength	Viscosity	Degree of Cure	HPLC	FTIR
				Filled Hole				
				Strength, Modulus, Strain to Failure				
			Transverse	Open Hole Tensile Strength				
Shear	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Reaction Rate	Heat of Reaction	Volatile Content	Temperature
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Volatile Type	Resin Cost	Density	Resin Cure Shrinkage
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	CTE	Thermal Conductivity	Specific Heat	Kinetics Model
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Viscosity Model	Intellectual Property Issues	HPLC	FTIR
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Health and Safety Information	Morphology	Ingredient Suppliers	Cured Resin
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Tensile Stress to Failure	Young's Modulus, Tensile	Tensile Strain to Failure	Glass Transition Temperature
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Density	Modulus as a Function of Temp	CTE	Thermal Conductivity
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Solvent Resistance	Specific Heat	Bulk Modulus	Shear Modulus
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Poisson's Ratio	Coefficient of Moisture expansion	Compression Strength	Compression Modulus
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Mass Transfer Properties	Viscoelastic Properties	Toughness Properties	Tg, Wet
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	CME	Solvent (Moisture) Diffusivity	Solvent Resistance	Fiber Surface
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Sizing Type	Fiber Surface Roughness	Surface Chemistry	Requirements
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Hand Cutting	Hand Layup	Hand Layup	Hand Layup
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Filament Diameter	Filament Count	Transverse Bulk Modulus	Young's Modulus
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Shear Modulus, 16	Shear Modulus, 16	Poissons Ratio, 12	Poissons Ratio, 13
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Compression Strength	Cost	Tg	wet Tg
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Health and Safety	Fiber Surface	Sizing Type	Fiber Surface Roughness
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Surface Chemistry	Requirements	Spool Information	Indirect Materials ID/Compatibility
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Tack, Original	Tack, Out Time	Tack, Freezer Time	Variability, Dimensions
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Variability, Angle	Specification, Draft Items/Areas	Specification, Preliminary	Specification, Final
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Tack, Original (lay down and removal)	Tack, Out Time (lay down and removal)	Tack, Freezer Time	Variability, Dimensions
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				
Other	Lamina		Longitudinal	Strength, Modulus, Strain to Failure, Poissons 1 & 2	Variability, Angle	Specification, Draft Items/Areas	Specification, Preliminary	Specification, Final
				Strength, Modulus, Strain to Failure, Poissons 1 & 2				
			Through Thickness	Strength				
				Modulus				

# Summary



- **Multiple Discipline Perspective Integrates Requirements and Conformance to Requirements**
- **Multiple Discipline Conformance Activities Covers The Spectrum of All Areas and Items for Material Insertion**
- **Certification and Qualification is Very Complex**
- **Primary Emphasis is Risk Reduction Relative to Applications**

# Ending



“The best information on a new material are the first things heard about it. It only goes downhill from there.”

*Quote Attributed to Flake Campbell Jr.*

